SURVIVAL OF NEWLY GERMINATED PONDEROSA PINE SEED ON THE LINCOLN NATIONAL FOREST

Robert L. DeVelice

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Resources Development Internship Program
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To those without whom this
paper could not have been
written.

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SURVIVAL OF NEWLY GERMINATED PONDEROSA PINE SEED ON THE LINCOLN NATIONAL FOREST

Robert L. DeVelice and Bruce A. Buchanan[1]

OBJECTIVE

Study the feasibility of using newly germinated ponderosa pine, Pinus ponderosa, Laws, seed as a reforestation technique on the Lincoln National Forest.

ABSTRACT

A six-week study in southcentral New Mexico during the summer of 1974 revealed that the technique of planting newly germinated ponderosa pine seed may provide a feasible method of reforestation on burned areas. The lead time for conventional methods of reforestation normally require at least two years, which is considerably longer than the 10 - 15 days required for the method of planting newly germinated seed. Thus, a major reforestation operation could be initiated on short notice at times when environmental conditions are optimum for the survival and growth of seedlings.

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[1] WICHE Student Intern and Assistant Professor of Forest Soils, Agronomy Department, New Mexico State University, respectively.

SURVIVAL OF NEWLY GERMINATED PONDEROSA PINE SEED ON THE LINCOLN NATIONAL FOREST

Robert L. DeVelice and Bruce A. Buchanan

INTRODUCTION

Areas which were once forested, but are now inadequately stocked as a result of logging or fire, must be reforested for use by future generations. Forest use may take the form of wood, water, wildlife, forage, or recreation. Another type of use which is of increasing importance, is aesthetics. Most often these demands on the forest exceed the rate at which these understocked areas become reforested naturally. It is therefore necessary that artificial reforestation be initiated.

The conventional method of planting 2 - 0[2] nursery stock has generally given limited success on the Lincoln National Forest. Survival under normal conditions averages 10 percent and under favorable conditions 30 percent (Buchanan, 1974). One of the limiting factors to nursery stock survival is shallow and/or extremely rocky soils. Foiles and Curtis (1973) suggest that 45 to 60 cm of soil are needed for the survival of ponderosa pine nursery stock. A second important limiting factor is the amount of precipitation. Reforestation attempts in years when precipitation is below normal often fail.

Two or three years are required for the planning of a commercial reforestation operation when using nursery stock. This elapse of time beginning when the seed is planted in the nursery bed and ending at the time of field planting is referred to as lead time. Reforestation with newly germinated seed should require only 10 - 15 days of lead time. Thus, a commercial planting operation using newly germinated seed may be easily initiated when environmental conditions are at an optimum. The expected reduction in cost of growing and planting germinated seed compared to nursery stock may permit the use of techniques to aid survival, e.g. animal damage retardants and supplemental water.

LITERATURE REVIEW

The use of newly germinated seed for reforestation has been investigated in southern California by Anderson and Williamson (1974) using coulter pine seed (Pinus coulteri D. Don.). In their study, trees which had screen caps of 6.4 mm mesh placed over them obtained an eight-month survival record of 59 percent, those which were treated with a bird and rodent repellant (Arasan 42-S) displayed 36 percent survival, and untreated seedlings had a survival record of 28 percent. During the first four weeks

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[2] The first number (2) designates the number of years in the nursery bed and the second number (0) is the number of years in the transplant bed.

after seedlings were planted, 90 percent of the loss was a result of bird and rodent depredation. Drought caused moisture stress to occur in the fourth week, and from that point on the greatest cause of seedling mortality was drought.

It was also discovered by Anderson and Williamson (1974) that one man could plant about 100 of these newly germinated seeds per hour, while bare-root nursery stock could only be planted at a rate of 20 trees per hour.

Investigations are needed to determine the feasibility of newly germinated seed as a reforestation technique for the Lincoln National Forest, using ponderosa pine seed.

STUDY AREA

The Lincoln National Forest of southcentral New Mexico has a total area of 446,567 ha. The area classified as accessible commercial forest land is 108,091 ha. It is estimated that 35 percent of this accessible commercial forest land is ponderosa pine and southwestern white (Pinus strobiformis Sarg.) and 20 percent is inadequately stocked.[3] These inadequately stocked areas are largely a result of extensive fires in this forest. This study was conducted in areas that were once stocked with ponderosa pine but which are now poorly stocked as a result of fire.

The average precipitation of the areas studied varies from 48 cm to 65 cm per year at elevations of 2135m (7000 ft) and 2440m (8000 ft), respectively (USWB). The average monthly precipitation from two weather stations located near the study areas is given in the Appendix, Table 4. Nearly 40 percent of the precipitation falls during July and August. However, during the months of April, May and June, only 15 percent of the annual precipitation is received. This three month period is known as the spring drought.

METHODS

Irrigated Trial

In an effort to provide experience in planting techniques, a plot was planted on July 10, 1974, and July 27, 1974. This plot contained two seedlings in each of 40 scalps. Scalps were 50 cm on a side and were made with a McLeod fire rake. The purpose of scalps is for eliminating competing vegetation. The first 20 scalps were planted on June 10th using seeds germinated at room temperature on the surface of vermiculite sandwiched between sheets of burlap in a flat. The seedlings were planted in holes

[3] Unpublished report; Supervisors' Office, Lincoln National Forest, Alamogordo, New Mexico.

made with a grub hoe. Ten of the remaining 20 scalps were planted with seedlings grown in petri dishes at room temperature and ten with seedlings grown near the planting site. This plot was watered three times a week for two months.

Seed

Ponderosa pine seed that had been collected on the Lincoln National Forest was soaked in water in a refrigerator at a temperature of 5°C for one week. Seeds were germinated on the surface of vermiculite placed between sheets of filter paper in petri dishes (size 100m x 15mm). Thirty seeds were placed in each petri dish. The petri dishes were then placed in a refrigerator to retard germination. Dishes were removed daily over a four-day period. This procedure was used to insure that trees of comparable root length could be planted during the anticipated four-day planting operation.

Petri dishes removed from the refrigerator were stored under two germination conditions:

1. germination in room temperatures of between 26 and 32°C
2. germination in environmental conditions on the Lincoln National Forest

The seeds germinated at room temperatures (controlled environment) and those germinated in the field (natural environment) were watered three times a week. The elapse of time was nine days from when the seeds were first watered until they were planted.

Plots

Due to the great diversity of soil types, slopes, and aspects encountered in the ponderosa pine region of Lincoln National Forest, the positions of the various research plots were also diverse. Hopefully, the results of this study yield an accurate representation of newly germinated seed performance on the varied environments indigenous to the burned areas.

There were 13 plots designated. These plots were divided into two sets, A and B. There were five plots in set A and eight in set B. The five plots in set A were positioned within an area of 0.5 ha on a northwest aspect in a burn that occurred on April 6, 1974 (vegetation was very limited on this area at the time of planting). The set A plots were all 1000m^2 in size, and were located on approximately a 20 percent slope. The burned trees on these five plots had an average density of 730 trees per hectare. Before planting, the plots were thinned to five tree densities relative to their original tree density:

plot 1 - 1/10 of all trees on plot were cut
plot 2 - 1/2 of all trees on plot were cut
plot 3 - all trees on plot were cut
plot 4 - no trees on plot were cut
plot 5 - 1/5 of all trees on plot were cut
(the above cutting systems were randomly assigned)

The trees were cut leaving a stump approximately 1m tall. The felled trees were then bucked and positioned parallel to the contour of the slope in hopes that they would act as effective erosion controls. The remaining standing trees and stumps were numbered.

The eight plots in set B were located on the following aspects (two per aspect): northeast (NE), northwest (NW), southeast (SE), and southwest (SW). The two plots on each aspect were positioned on sites ranging from 5 to 10km from one another. These plots were positioned on burns ranging from 3 to 20 years of age (shrubs and grasses were prevalent). Plots were located over the full elevational range of ponderosa pine on the Lincoln National Forest.

Planting

Set A.: The scalps on the five plots in set A were $25cm^2$ in size and were made with a McLeod fire rake. Two scalps were positioned at the base of the first 16 trees or stumps numbered. One scalp was positioned on the south and one on the northwest side of the tree or stump. In each scalp, one newly germinated seed grown in the controlled environment and one grown in the natural environment were planted between July 4 and July 7. The seedlings were planted in holes made by a 2cm diameter "Oakfield" soil auger. Since soil moisture was low at the time of planting approximately 440ml of water was applied to each scalp. The lengths and configurations of seedling radicles were recorded at the time of field planting. Length was determined as the distance from the root tip to the point where green shoot was observed. Length measurements were rounded to the nearest 0.5 cm. Three classes of roots were judged based on the following root configuration: straight, bent, and coiled (see Appendix, figure 1).

Eight of the 16 scalps positioned on the northwest side of the tree or stump received a wood debris mulch and eight received no treatment. Identical treatments were applied to the 16 south scalps.

Set B: Thirty-two scalps were positioned within a $10m^2$ area on each of the eight set B plots. Scalps ranged in size from $25cm^2$ to $50cm^2$ and were made with a McLeod fire rake. Planting was similar to the set A plots except that it extended from July 5 through July 7.

Conical screen caps of 1.5mm mesh were placed over 16 of the scalps in an effort to discourage rodent and bird depredation. These caps also provided shading from insolation to the seedlings. One cap covered both of the newly germinated seeds in a scalp. The caps were 30cm high and were secured to the ground by four nails of 4cm length. Eight of the scalps with screen caps were mulched with wood debris in an effort to retain soil moisture. Of the remaining 16 scalps (without screen caps) eight were mulched and eight were left untreated.

Survival

Weekly records of survival were kept for the irrigated plot for a period of two months (June 10 to August 9). Survival was recorded at two periods after planting for the 13 plots. The first record was taken during

the week of July 24, 2.5 weeks after planting, and the second record was taken during the week of August 9, five weeks after planting.

Soil Moisture

Soil moisture was taken on all plots at planting and on the days that survival was recorded. These soil moisture samples were collected from a depth of 0 to 10cm with a 2cm diameter "Oakfield" soil auger. The samples were weighed when wet, then were dried at 105°C for 24 hours, and then re-weighed. The percent moisture was calculated for a dry soil weight basis.

Precipitation

Two precipitation gauges were located in the area of the A plots and two gauges at each of the B plots. All gauges were read on the days when survival was recorded. The gauges were modified seamless aluminum cans used to collect rainfall.

RESULTS

Survival

Irrigated trial: The irrigated plot used to gain experience in planting technique resulted in 18 and 15 percent survival, respectively, one and two months from the June 10 planting. Survival was 58 percent after one month for the June 27th planting.

General: The overall survival of newly germinated ponderosa pine seed on the 13 study plots was 39 percent in July (2.5 weeks after planting) and 33 percent in August (5 weeks after planting). An attempt was made to assess the reason for the death of newly germinated seed. The death record five weeks after planting was 1) 3 percent eaten by rodents, 2) 11 percent dead as a result of "damping off" disease, or erosion, and 3) 53 percent "non-emerged". The seedlings that were classified as non-emerged may have been eaten by rodents or birds, have been incorrectly planted, or had not emerged at time of record.

Treatments used: There was a slight trend for seedlings planted on the northwest sides of stumps on the set A plots to have a higher survival than those on the south sides, Table 1. However, the difference was not significant at the 95 percent level. There was little effect from mulching on these plots.

A comparison of treatments tested in set B plots, Table 1, indicates that seedlings grown under cap and cap mulch treated scalps exhibited a significantly higher survival than those grown on scalps without caps. Mulching had no significant effect on these plots.

Table 1. Survival of newly germinated ponderosa pine seedlings for set A and set B plots, by treatment.

Treatment	# of trees planted	Percent survival after 2.5 weeks	Percent survival after 5 weeks
SET A			
No treatment, planted northwest side of stump	80	43	28a[1]
Mulch, planted northwest side of stump	80	38	29a
No treatment, planted south side of stump	80	34	21a
Mulch, planted south side of stump	80	24	20a
SET B			
No treatment (control)	128	20	16b
Mulch (wood debris)	128	30	20b
Screen cap	128	67	68c
Screen cap, mulch	128	61	58c

[1] Survival percentages followed by the same letters are not significantly different at the 95% level--(Z test). There was no comparison made between sets A and B.

Fifteen percent of the screen caps had been knocked over from the time of planting to the 2.5 week survival check. These caps were replaced when the 2.5 week survival check was made. Twenty-two percent of the caps were knocked down when the fifth week survival check was made. The majority of the caps knocked over were attributed to cattled activity.

Plot variation: The five-week survival on the set A plots revealed that seedlings on the 1/2 cut plot displayed significantly higher survival than the other plots in that set, Table 2. The average surface soil moisture content had nearly doubled on the set A and set B plots from the time that the trees were planted (average 11 percent) to the time that the 2.5 week survival check was made (average 20 percent). At the five-week survival check the soil moisture averaged 26 percent for all plots. Five weeks after planting no apparent differences in survival of newly germinated seed were evident between plots on the four aspects considered in set B, Table 2.

Precipitation averaged 6.2 cm to 10.2 cm at the 2.5 and 5 week survival checks, respectively on the Set A and set B plots. The average total precipitation was 16.4 cm (6.5 in)for the five week period, Table 2.

Root length and configuration: There was no apparent difference in the survival of seedlings with straight or bent roots, Table 3. Also, little difference was evident in the survival of newly germinated seeds with root lengths ranging from 0.25 to 4.75 cm.

There were 19 seedlings with coiled roots in the 175 newly germinated seeds evaluated for root lengths and configurations. Coiled roots between 1.75 cm to 3.0 cm and 3.0 to 4.75 cm lengths had 20 percent and 27 percent survival, respectively.

Germination environment: There was no apparent difference in survival between seeds germinated in either the natural or controlled environments, for the set B plots, Table 4. In contrast, for the set A plots, the seed germinated in the natural environment had a significantly higher survival than those germinated in the controlled environment, Table 4.

Mortality.

The greatest cause for a lack of survival was the high percentage of non-emerged trees, Table 5. The non-emerged group had a significantly higher percentage of mortality than the animal or damping groups. In the set A plots the damping group had significantly higher mortality than the animal group. In set B plots the damping and animal group mortality was not significantly different.

DISCUSSION AND CONCLUSIONS

Survival

The survival of newly germinated seed after five weeks is used as the basis for most of the discussion and conclusions presented. It is important

Table 2. Slope, aspect, soil moisture, rainfall, and survival for 13 plots planted with newly germinated ponderosa pine seed.

Plot #	Cut	Slope (%)	Aspect	Surface (0-10cm) soil moisture(%) weeks[1]			Precipitation (cm) period[2]		Survival % weeks	
				0	2.5	5	0-2.5	2.5-5	2.5	5
SET A										
1	1/10	18	NW	4	12	19	6.49	7.85	11	6a[3]
2	1/2	18	NW	8	17	25	6.49	7.85	66	48d
3	1/1	20	NW	16	28	30	6.49	7.85	39	28c
4	0/1	20	NW	7	14	21	6.49	7.85	38	23bc
5	1/5	25	NW	16	19	29	6.49	7.85	17	16ab
SET B										
6	NA[4]	18	NE	4	18	19	5.94	ND[5]	47	42e
7	NA	42	NW	14	18	20	5.26	4.82	47	46e
8	NA	33	SE	8	24	27	4.54	17.99	33	31e
9	NA	13	SW	22	20	20	6.25	15.56	44	41e
10	NA	8	SW	6	12	14	4.08	ND	41	36e
11	NA	35	SE	14	34	46	8.19	14.81	45	42e
12	NA	42	NW	12	22	23	7.24	10.72	59	58e
13	NA	11	NE	9	22	26	6.76	8.89	34	31e
		Average		11	20	25	6.21	10.19	39	33

[1] Weeks - weeks after planting

[2] Period - period of weeks after planting precipitation was recorded

[3] Survival percentages followed by the same letters are not significantly different at the 95% level--(chi square test). There was no comparison made between set A and set B.

[4] NA - not applicable

[5] ND - no data

Table 3. Survival of newly germinated ponderosa pine seed planted on 13 plots, in relation to root configuration and root length.

Root length (cm)	Root Configuration	Number of trees considered	Survival after 2.5 weeks	Survival after 5 weeks	
0.25 - 1.75	Straight	26	42	35a[1]	I
	Bent	26	50	50a	
1.75 - 3.25	Straight	26	46	38a	I
	Bent	26	50	38a	
3.25 - 4.75	Straight	26	35	35a	I
	Bent	26	50	42a	

[1] Survival percentages followed by the same letter indicate no significant difference between root configurations. Percentages followed by the same Roman numeral indicate no significant difference between root lengths. Significance tested at 95% by Z test.

Table 4. Survival of newly germinated ponderosa pine seed planted on 13 plots, in relation to the seed germination environment.

Seed germination environment	No. of trees planted	Percent survival after 2.5 weeks	Percent survival after 5 weeks
SET A plots (1-5)			
Control	160	27	18b[1]
Natural	160	42	31c
SET B plots (6-13)			
Control - room temperature	256	43	39a
Natural - forest temperature	256	46	42a

[1] Survival percentages followed by the same letter indicate no significant difference (95% level - Z test) between seed germinated under different environments. There was no comparison made between set A and set B.

NOTE: Table 5 of the text is partially invalid, this is the corrected version of that table.

Table 5. Causes of mortality of germinated seed for 13 plots.

Plot set	Number of trees planted	Animal (%)[1]		Damping (%)[2]		Non-emerged (%)[3]	
		Weeks[4]					
		2.5	5	2.5	5	2.5	5
A	320	2	4 a	4	13 b	60	59 c
B	512	1	2 a	6	9 a	49	48 b

1 Animal - trees had obviously died from being eaten by animals (mostly small rodents)

2 Damping - trees had died from either damping-off disease or silted in as a result of erosion.

3 Non-emerged - trees had either not emerged at time of record, emerged and were eaten, or were never going to emerge as a result of misplanting.

4 Weeks - weeks after planting

5 Mortality percentages with the same letters beneath them indicate no significant difference (95% level-chi-square) in mortality. There was no comparison made between set A and set B.

to recognize that normally conclusions are drawn from one and often three years of survival data. This study was not designed to fully evaluate the potential of newly germinated seed reforestation but to consider the feasibility of a new reforestation technique and to decide if additional research is merited.

Treatments used: Screen caps provide seedlings with the greatest chance of survival. Anderson and Williams (1974) found very similar results using the screen cap. This enhanced survival is largely a result of protection from rodent and bird depradation. Shading is also a factor. Seedlings planted under caps are thought to be subjected to less moisture stress than non-capped seedlings. Shade from the cap should lower the amount of evapotranspiration. Because of these two protective traits (rodent and shade) screen caps are considered as desirable aids to the survival of newly germinated seed. The economics of using screen caps merits investigation.

The purpose of mulching seedlings is to maintain high levels of soil moisture at the soil surface for the seedlings. For the duration of this study, soil moisture was probably not limiting to seedling survival because average precipitation exceeded 18 cm on the study sites. The lower survival of seedlings on mulched and unmulched scalps as compared to capped scalps is thought to be a result of the vulnerability of these uncapped seedlings to rodent and bird depredation.

The similarity of survival of seedlings on mulched and unmulched scalps would suggest that mulching is not an effective aid to survival. Findings of Rietveld and Hiedmann (1974) similarly suggested that mulching has little effect on survival.

Plot variation: The similarity of seedling survival on the plots of set B is considered the result of near optimum environmental conditions. The normal effects of slope and aspect, i.e. cool and wet north aspects and hot and dry south aspects could not be as well expressed during this study period (average of 16.4 cm of precipitation) as might be expected in a dry season. The effect of slope and aspect will likely be evident in later records of survival. Since the expected difference in environmental conditions were not well expressed, because of the optimal conditions described above, the comparison of planting on northwest and south sides of stumps also showed little difference in survival.

The lack of similarity in seedling survival on the plots in set A is attributed to the effect of thinning the burned trees. However, the results seem very confusing and are considered inconclusive at this point. An additional study being conducted by B. A. Buchanan (project supervisor) is specifically designed to evaluate the effects of thinning on these plots.

Germination environment: The hypothesis was that seed germinated near the planting site would have a greater survival rate than seed germinated at constant warm temperatures of 21°C - 25°C. A common practice in reforestation is to condition seedlings to the local environment before planting. We thought a similar situation would be true for newly germinated

seed. An alternative would be to germinate seed at warm constant temperatures which produces seedlings faster than ones germinated under variable day-night temperatures.

The findings concerning germination environment seem contradictory when comparing the survival for the set A and set B plots. Survival on set A plots, which were within a 1 km distance of the germination site, followed the expected hypothesis and leads to the conclusion that seed should be germinated on the planting site. Survival on the set B plots did not change with the different seeds from the two germination environments. A possible explanation for this lack of agreement is that the set B plots covered a wide range of elevations, and thus temperatures. This variation may have negated the effect of germination environment.

Root length and configuration: Root length for the seedlings considered (0.25 cm - 4.75 cm) does not contribute to variation in seedling survival. Anderson and Williamson (1974) suggested that roots of 1.27 cm - 3.81 cm were optimum lengths for planting. It is important to know that the shortest root class evaluated (0.25 - 1.75 cm) did not reduce survival. These shorter root lengths would be the easiest to grow if a short lead-time for production were necessary.

The straight and bent root (see Appendix, fig. 1) configuration has little effect on survival. However, one configuration that is not desirable is the coiled root. Although only a few samples were found among the germinated seed, survival was reduced as compared to straight or bent roots. The coiled root may not allow the seedling to emerge correctly and could cause an undesirable growth form of root and/or shoot.

Mortality

Studies by Buchanan (1974) and Wollum et al. (1973) show that animal damage on containerized seedlings often exceeds 50 percent in open burned areas. Buchanan (1974) found for a one year study that damage to three and four-month-old containerized seedlings will often be double that of two-year nursery stock. These young newly germinated seedlings are therefore extremely vulnerable to rodent damage. The use of screen caps which greatly enhance survival would indicate that success of newly germinated seed will greatly depend on the effectiveness of rodent control.

Although only a small percentage of seedling mortality could be assessed directly to animal damage, rodents probably accounted for a large proportion of mortality in what was designated as the non-emerged group. Damping-off is not of great concern.

SUMMARY

The planting of newly germinated seed does provide a feasible method of reforestation. The fact that lead time is short for this technique allows commercial reforestation efforts to be coordinated with periods of optimum precipitation.

RECOMMENDATIONS

1. Screen caps of 1.5 mm mesh positioned on 50 cm^2 scalps should be used as important aids for enhancing seedling survival.

2. Seeds should be germinated under temperature conditions indigenous to the planting site.

3. Seedlings with either straight or bent root configurations and with root lengths between 0.25 cm and 1.75 cm in length should be planted.

4. Additional research should be initiated to investigate the long term success of newly germinated seed in a commercial operation.

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APPENDIX

Table 1. Percent survival of newly germinated ponderosa pine seedlings on each set A and set B plot, by treatment (16 trees were planted for each treatment on each plot).

Plot #	Weeks after planting	SET A			
		No treatment (control)	Mulch	No treatment (control)	Mulch
		NW side of stump		S side of stump	
1	2.5	6	19	13	6
	5	6	13	6	0
2	2.5	88	63	63	50
	5	63	56	31	44
3	2.5	38	44	31	44
	5	19	38	19	38
4	2.5	44	56	38	13
	5	25	31	25	13
5	2.5	38	6	13	13
	5	25	6	25	6
		SET B			
		No treatment (control)	Mulch	Screen cap	Mulch
6	2.5	38[1]	31	63	63
	5	31	39	63	50
7	2.5	0	19	88[1]	88
	5	0	13	81	81
8	2.5	0	0	69	63
	5	0	0	63	56
9	2.5	31	44	44	56
	5	31	31	44	56
10	2.5	31	19	63	50
	5	13	19	63	50
11	2.5	19	31	75	56
	5	19	19	75	56
12	2.5	25	56	88	69
	5	25	50	88	69
13	2.5	13	19	63	44
	5	13	13	63	44

[1] The reason for the higher survival on the 5th week than after 2.5 weeks is due to the emergence of seedlings which were classified at non-emerged at the 2.5 week reading.

APPENDIX

Table 2. Causes of mortality of newly germinated ponderosa pine on each set A and set B plots (64 trees were planted on each plot).

Plot set and #	Percent dead					
	Animal[1]		Damping[2]		Non-emerged[3]	
	Weeks[4]					
	2.5	5	2.5	5	2.5	5
SET A						
1	0	0	0	5	89	89
2	2	3	3	20	29	29
3	8	14	5	10	48	48
4	2	2	8	23	52	52
5	0	0	2	5	81	79
SET B						
6	3	6	11	13	39	39
7	0	0	2	3	51	50
8	0	0	5	7	62	62
9	0	0	8	12	48	47
10	6	9	12	16	41	39
11	0	2	0	3	55	53
12	0	0	3	5	38	37
13	0	2	6	9	60	58

[1] Animal - trees had obviously died from being eaten by animals (mostly small rodents).

[2] Damping - trees had died from either damping-off disease or silted in as a result of erosion.

[3] Non-emerged - trees had either not emerged at time of record, emerged and were eaten, or were never going to emerge as a result of misplanting.

[4] Weeks = weeks from planting

APPENDIX

Table 3. Locations of the eight plots designated as set B.

Plot #	Area	Location description[1]
6	Curtis Canyon	Double plot below raod (plot 23)
7	Curtis Canyon	Lunch Canyon (plot 44)
8	Jim Lewis Canyon	Short Climb Hill, RIGHT (plot 9)
9	Jim Lewis Canyon	Cold Toes Canyon, RIGHT (plot 54)
10	Rogers Ruins	Burn Lookout (plot 16)
11	Monument Canyon	Klan Plot
12	Denny Hill	Parking Bend (plot 30)
13	Denny Hill	Center Bench Plot, lower (plot 19)

1. Seven of the eight plots were positioned on already existing plots designated by Dr. B. A. Buchanan (project supervisor) for his containerized seedling research. The plot number following each location description corresponds to Dr. Buchanan's plots.

Location of the set A plots: The five set A plots are located on Sacramento Methodist Assembly land near the village of Sacramento, New Mexico. They are positioned on a bench approximately 50m west of an outdoor chapel called "the point of silence".

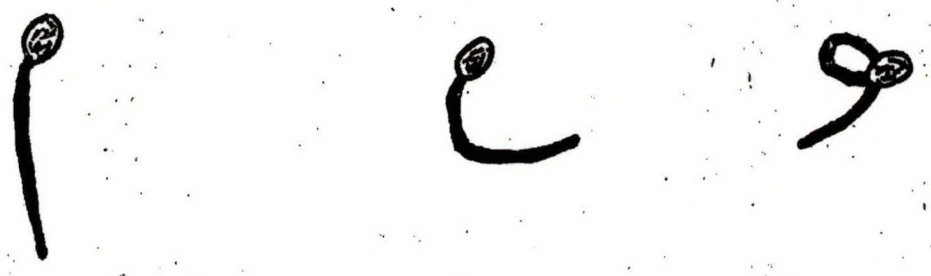
APPENDIX

Table 4. Average monthly and annual precipitation at two weather stations (Mayhill and Cloudcroft) located near the study areas.

Month	Locations	
	Mayhill	Cloudcroft
	Precipitation (cm)	
January	1.90	4.57
Feburary	1.85	4.32
March	2.01	4.14
April	1.50	2.16
May	3.12	2.77
June	4.83	4.72
July	8.97	14.71
August	9.68	12.01
September	7.47	6.02
October	3.68	4.09
November	0.97	2.16
December	2.03	3.71
Annual Average	48.01	65.38

APPENDIX

Figure 1. Visual appearance of straight, bent, and coiled newly germinated seed roots.



Straight root Bent root Coiled root

RECOMMENDATIONS FOR FUTURE STUDIES

1. Results of this study warrant the further observation and evaluation of newly germinated seed on the already existing plots on the Lincoln National Forest.
2. A 2 - 0 bare root stock control should be implemented in future studies.
3. Determine a method of anchoring caps which would keep them from being knocked over by cattle.
4. Different kinds of animal damage retardants need evaluation.
5. Evaluate the use of anti-transpirants.
6. Study the effects of mycorrhizae on seedling growth and survival.
7. Determine the optimum depth of planting newly germinated seed.
8. Evaluate the growth of seedlings after out planting.
9. Evaluate the cost of a newly germinated seed reforestation operation against the cost of conventional methods.
10. Evaluate the use of genetically improved seed.

This intern report was read and accepted by a staff member at:

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This report was completed by a WICHE intern. This intern's project was part of the Resources Development Internship Program administered by the Western Interstate Commission for Higher Education (WICHE).

The purpose of the internship program is to bring organizations involved in community and economic development, environmental problems and the humanities together with institutuions of higher education and their students in the West for the benefit of all.

For these organizations, the intern program provides the problem-solving talents of student manpower while making the resources of universities and colleges more available. For institutions of higher education, the program provides relevant field education for their students while building their capacity for problem-solving.

WICHE is an organization in the West uniquely suited for sponsoring such a program. It is an interstate agency formed by the thirteen western states for the specific purpose of relating the resources of higher education to the needs of western citizens. WICHE has been concerned with a broad range of community needs in the West for some time, insofar as they bear directly on the well-being of western peoples and the future of higher education in the West. WICHE feels that the internship program is one method for meeting its obligations within the thirteen western states. In its efforts to achieve these objectives, WICHE appreciates having received the generous support and assistance of the Economic Development Administration; the Jessie Smith Noyes Foundation; the National Endowment for the Humanities; the National Science Foundation; the Division of Education of HEW; and of innumerable local leaders and community organizations, including the agency that sponsored this intern project.

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